SCANNING ELECTRON MICROSCOPY, CATHODOLUMINESCENCE, AND RAMAN SPECTROSCOPY OF EXPERIMENTALLY SHOCK METAMORPHOSED QUARTZITE.
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Cathodoluminescence (CL) is an optical phenomenon that is based on the generation of visible radiation through sample excitation by high-energy electrons (in general, with energies of the incident beam of 5-25 kV, the depth of penetration is 1-3 µm). Wavelengths of the cathodoluminescence emissions range from the ultraviolet (UV) to the infrared (IR) and result from a variety of defects (e.g., various structural imperfections, such as poor ordering, radiation damage, shock damage) and impurities in the crystal structure of a mineral.So far, no systematic study has been made regarding the changes of CL properties (optical appearance in CL images, and the characteristics of CL spectra) with shock pressure in quartz. As quartz is one of the most common rock-forming minerals, for which ample information on shock-related changes of a large variety of mineralogical, crystallographic, and petrographic parameters exists, we undertook-such an investigation.

Generally, the luminescence of quartz shows different CL colors depending on its origin. Previous work on CL properties of shocked quartz is limited. An early study in the 1980s, showed that quartz from intrusive igneous and high-grade metamorphic rock shows darker purple-blue CL, whereas quartz from low-grade metamorphic rocks exhibit reddish-brown CL, and that shocked quartz from the Cretaceous-Tertiary (K/T) boundary exhibits CL colors similar to those of low-grade metamorphic quartz. These observations were used to demonstrate that shocked quartz from the K-T boundary was not derived from volcanic sources. Newer studies include CL studies of shocked quartz grains from the Mjølnir impact structure (Barents Sea) in comparison with quartz from a variety of other sources, and a study of planar deformation features (PDFs) in shocked quartz from the Ries crater, Germany, using a SEM-CL imaging facility.

We studied unshocked and experimentally (at 12, 25, and 28 GPa, with 25, 100, 450 and 750 °C pre-shock temperatures) shock-metamorphosed Hospital Hill quartzite from South Africa, in a first attempt to use cathodoluminescence (CL) images and spectroscopy, as well as Raman spectroscopy, to document any systematic pressure or temperature effects that might be obvious from these techniques, and that could be used in shock barometry.

In general, CL images of all samples show CL-bright luminescent patchy areas and bands in otherwise non-luminescent quartz and CL-dark irregular fractures, which could be related to the microdistribution of some activator elements (e.g., Al, Li, Na). Fluid inclusions are dominant in CL images of the 25 GPa sample shocked at 750 °C and of the 28 GPa sample shocked at 450 °C. Only the optical image of the 28 GPa sample shocked at 25 °C exhibits distinct planar deformation features (PDFs). Cathodoluminescence spectra of unshocked and experimentally shock-deformed samples show broad bands in the near-ultraviolet range and the visible light range at all shock stages, indicating the presence of defect centers on, e.g., SiO_4 groups. No systematic change in the appearance of the CL images was obvious, but the CL spectra do show changes between the shock stages. The energy diagrams of the cathodoluminescence emission centers indicate that recombination centers or traps are closely-spaced in the band gap between conduction and valence bands of quartz, and that the spacing changes as a function of the increasing shock pressure, causing non-radiative (e.g., no photon emission) emission or broad bands in the near-ultraviolet region in the CL spectrum.

The Raman spectra show changes between the various shock stages. The stretching (symmetric and antisymmetric) vibrational modes are characteristic for quartz in the unshocked and 12 GPa samples. In the 25 and 28 GPa samples, the intensity of the background fluorescence is higher compared to the other samples. Broad bands of these spectra might be relics of O-Si-O stretching vibrational modes. It appears that some of the CL and Raman spectral properties can be used in shock barometry.

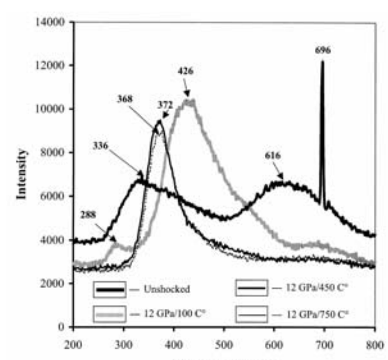

Fig. 1. Example of CL spectra of unshocked quartz and shocked at 12 GPa. A sift is obvious.